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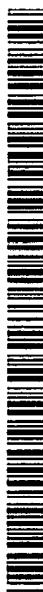
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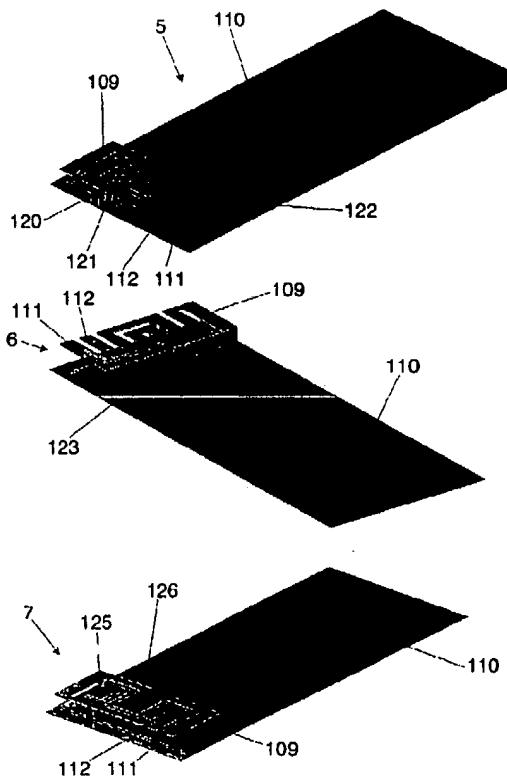
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(54) Title: MULTIBAND ANTENNA FOR HANDHELD TERMINAL



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(57) Abstract: The present invention relates generally to a new family of antennas with a multiband behaviour and a reduced size. The general configuration of the antenna consists of a multilevel structure which provides the multiband behaviour, combined with a multilevel and/or space-filling ground-plane. The multilevel structure consists of two arms of different length that follow a winding parallel path spaced by a winding parallel gap (parallel to the arms) with a substantially similar shape as each of said arms, that is, with a similar winding path as the arms. The resulting antenna covers the major current and future wireless services, opening this way a wide range of possibilities in the design of universal, multi-purpose, wireless terminals and devices.



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MULTIBAND ANTENNA FOR HANDHELD TERMINAL

## OBJECT AND BACKGROUND OF THE INVENTION

5 The present invention relates generally to a new family of antennas with a multiband behaviour and a reduced size. The general configuration of the antenna consists of a multilevel structure which provides the multiband behaviour, combined with a multilevel and/or space-filling ground-plane. A  
10 description on Multilevel Antennas can be found in Patent Publication No. WO01/22528. A description on several multilevel and space-filling ground-planes is disclosed in Patent Application PCT/EP01/10589. In the present invention, a modification of said multilevel structure is introduced such that the frequency bands of the antenna can be tuned simultaneously to the main  
15 existing wireless services. In particular, the modification consists of splitting the multilevel structure in two arms of different length that follow a winding parallel path spaced by a winding parallel gap (parallel to the arms) with a substantially similar shape as each of said arms, that is, with a similar winding path as the arms. Also, when the multilevel antenna structure is combined with a  
20 multilevel and/or space-filling ground-plane, the overall performance of the antenna is enhanced, increasing the bandwidth and efficiency of the whole antenna package. Due to the small size, high efficiency and broad band behaviour of the antenna, it is especially suitable for, but not limited to, the use in small handheld terminals such as cellular phones, PDAs or palm-top  
25 computers.

Although publications WO01/22528 and WO01/54225 disclose some general configurations for multiband and miniature antennas, an improvement in terms of size, bandwidth, and efficiency is obtained in some applications when said  
30 multilevel antennas are set according to the present invention. Such an improvement is achieved mainly due to the particular two-arm multilevel geometry of the antenna, used in conjunction with the design of the ground-plane and the interaction of both. Also, in some embodiments the antenna

features a single feeding point and no connection to the ground-plane is required, which introduces a significant advantage in terms of manufacturing cost and mechanical simplicity.

- 5 A multilevel structure for an antenna device, as it is known in prior art, consists of a conducting structure including a set of polygons, all of said polygons featuring the same number of sides, wherein said polygons are electromagnetically coupled either by means of a capacitive coupling or ohmic contact, wherein the contact region between directly connected polygons is
- 10 narrower than 50% of the perimeter of said polygons in at least 75% of said polygons defining said conducting multilevel structure. In this definition of multilevel structures, circles, and ellipses are included as well, since they can be understood as polygons with a very large (ideally infinite) number of sides. An antenna is said to be a multilevel antenna, when at least a portion of the antenna
- 15 is shaped as a multilevel structure.

A space-filling curve for a space-filling antenna, as it is known in prior art, is composed by at least ten segments which are connected in such a way that each segment forms an angle with their neighbours, i.e., no pair of adjacent segments

- 20 define a larger straight segment, and wherein the curve can be optionally periodic along a fixed straight direction of space if and only if the period is defined by a non-periodic curve composed by at least ten connected segments and no pair of said adjacent and connected segments define a straight longer segment. Also, whatever the design of such SFC is, it can never intersect with itself at any
- 25 point except the initial and final point (that is, the whole curve can be arranged as a closed curve or loop, but none of the parts of the curve can become a closed loop).

In some particular embodiments of the present invention, the antenna is tuned

- 30 to operate simultaneously at four bands, those bands being for instance GSM850, GSM900, DCS1800, and PCS1900. In other embodiments the antenna is able to cover also the UMTS band. There is not an example

described in the prior art of an antenna of this size covering such a broad range of frequencies and bands.

The combination of said services into a single antenna device provides an 5 advantage in terms of flexibility and functionality of current and future wireless devices. The resulting antenna covers the major current and future wireless services, opening this way a wide range of possibilities in the design of universal, multi-purpose, wireless terminals and devices that can transparently switch or simultaneously operate within all said services. For instance, the 10 simultaneous coverage of the GSM850, GSM900, DCS1800, and PCS1900 provides to a cell phone user with the ability to connect transparently to any of the two existing European GSM bands (GSM900 and DCS1800) and to any of the two American GSM bands (PCS1900 and the future GSM850).

## 15 SUMMARY OF THE INVENTION

The key point of the present invention consists of shaping a particular multilevel structure for a multiband antenna, such that said multilevel structure defines a winding gap or spacing between some of the characteristic polygons within said 20 multilevel structure, said gap featuring a substantially similar shape as the overall multilevel structure, that is, similar winding path.

When the multiband behaviour of a multilevel structure is to be packed in a small antenna device, the spacing between the polygons of said multilevel structure is 25 minimized. Drawings 3 and 4 in Figure 1 are some examples of prior art multilevel structures, where the spacing between conducting polygons (rectangles and squares in these particular cases) take the form of narrow gaps. One of the novelties of the present invention is that the shape of said gap has the same general winding shape as the two multilevel arms of the antenna. This 30 way, the coupling between the arms of the antenna enhances its broadband and multiband behaviour while further reducing the antenna size. Such a

configuration allows an effective tuning of the frequency bands of the antenna, such that with the same overall antenna size, said antenna can be effectively tuned simultaneously to some specific services, such as for instance the five frequency bands that cover the services GSM850, GSM900, DCS1800, and  
5 PCS1900.

It should be stressed that the present invention can be combined with the new generation of ground-planes described in the PCT application number PCT/EP01/10589 entitled "Multilevel and Space-Filling Ground-Planes for  
10 Miniature and Multiband Antennas", which describes a ground-plane for an antenna device, comprising at least two conducting surfaces, said conducting surfaces being connected by at least a conducting strip, said strip being narrower than the width of any of said two conducting surfaces. Although not strictly necessary, for some applications where a further enhancement of the overall  
15 bandwidth at each band is required, it is preferred that the portion of the ground-plane that is shaped as a multilevel or space-filling structure is the area placed underneath the so called radiating element, according to the present invention.

When combined to said ground-planes according to the present invention, the  
20 combined advantages of the newly disclosed antenna geometry and said ground-plane design are obtained: a compact-size antenna device with an enhanced bandwidth, enhanced frequency behaviour, enhanced VSWR, and enhanced efficiency.

25 The advantages of the antenna design disclosed in the present invention are:  
(a) The antenna size is reduced with respect to other prior-art multilevel and multiband antennas.  
(b) The frequency response of the antenna can be tuned to at least four frequency bands that cover the European and American GSM services:  
30 GSM850, GSM900, DCS1800, and PCS1900.

Those skilled in the art will notice that the same basic structure can be used to tune the antenna to include other frequency bands such as UMTS, Bluetooth™, and WLAN (such as for instance IEEE802.11 and Hyperlan2). The skilled in the art will also notice that current invention can be applied or combined to many 5 existing prior-art antenna techniques. The new geometry can be, for instance, applied to microstrip patch antennas, to Planar Inverted-F antennas (PIFAs), to monopole antennas, and so on. It is also clear that the same antenna geometry can be combined with several ground-planes and radomes to find applications in different environments: handsets, cellular phones and general handheld devices; 10 portable computers (Palmtops, PDA, Laptops,...), indoor antennas (WLAN, cellular indoor coverage), outdoor antennas for microcells in cellular environments, antennas for cars integrated in rear-view mirrors, stop-lights, bumpers, and so on.

## 15 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1. Drawings 1, 2, 3, and 4 show several prior-art multilevel structures for 20 antennas devices. All of them are constructed from rectangles. Drawings 3 and 4 show two particular cases where the spacing between polygons (rectangles) take the form of a narrow gap, which however does not feature a similar shape as the multilevel structure.

Figure 2. A prior-art multilevel structure formed by 8 rectangles. The gaps between rectangles do not feature a similar shape as the overall multilevel 25 structure.

Figure 3. Drawings 5, 6, and 7 show three particular embodiments of the present invention. A first conducting layer (109) is placed over a second conducting layer (110), said second conducting layer acting as a ground-plane or ground 30 counterpoise. Layer (109) takes the form of a multilevel structure, said structure being characterized by two arms (111) and (112), said arms defining a winding

path and a gap (122) between said arms, said gap (122) featuring a substantially similar shape as arms (111) and (112). In embodiment 5 the antenna is fed through a first strip (121) and shorted to ground through a second strip (120). In embodiment 6, rectangle (123) enhances the capacitive behavior with ground plane (110). Drawing 7 is same as 5, wherein four rectangles are merged into two rectangles (125) and (126).

Figure 4. Drawings 8, 9, 10 show three particular embodiments of multilevel antenna according to the present invention. All three embodiments include a multilevel ground-plane (110). In this three embodiments, the arrangement of polygons in said multilevel ground-plane (110) form a gap (113), (114), said gap being placed on (110) in the area underneath of first layer (109), according to the technique disclosed in the present invention.

Figure 5. Drawings 11 and 12 show two particular embodiments of the present invention. Again, area on (110) underneath first layer (109) is shaped as a multilevel structure according to the present invention.

Figure 6. Drawings 13, 14, and 15 show three particular embodiments of the present invention. Again, area on (110) underneath first layer (109) is shaped as a multilevel structure according to the present invention, where said multilevel structure is arranged such that the gaps between polygons take the form of eight gaps, four at each side of an axially arranged central polygon. Drawings 14 and 15 show same basic design as drawing 13, where some minor mechanical changes have been introduced both in first and second layer (109) and (110) to allow the integration of the antenna structure into a typical handset structure.

Figure 7. Drawing 16 shows a particular embodiment for multilevel structure on first layer according to the present invention. This particular multilevel structure is composed by 15 polygons of the same class (from 131, which can be either the starting or ending point, to 145, which can be either the ending or starting point),

said polygons defining a gap (122), said gap featuring a substantially similar winding shape as the two coupled arms on said multilevel structure.

5 Figure 8. Drawing 8 shows another preferred embodiment of a multilevel structure for the first layer (109) according to the present invention. In this arrangement, some edges in the polygons defining said multilevel structure are replaced by curves (146,147,148,149,150) to ease the mechanical integration of the antenna in the handheld device. A feeding point (158) could be seen on the first layer (109).

10

Figure 9. Shows a particular embodiment of a ground-plane (second layer 110) according to the present invention. The area underneath (109) is shaped as a multilevel structure with 4 polygons (154, 152, 155, 156), said polygons defining two gaps (157) and (153). To ease the integration within the mechanical structure 15 of typical handheld device, minor changes on the geometry are introduced which do not have a substantial effect on the essential electromagnetic behavior of the invention. For instance, some insets are done on the perimeter of larger rectangle (154), while two straight edges on polygons (155) and (152) are replaced by curved segments. Also, some small holes such as (151) are 20 distributed upon ground-plane. Said holes are made for mechanical or acoustic reasons and do not affect the general behavior of the invention.

Figure 10. Drawing 19 is same as drawing 18 with a slightly different arrangement of polygons on layer (110) such that gap (157) is not included.

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Figure 11. Drawing 20 shows a particular embodiment for multilevel structure on first layer according to the present invention. This particular multilevel structure is composed by 17 polygons of the same class (in this case, rectangles). Rectangle (180) can be either the starting or ending part of the multilevel arm of the 30 formation of the structure, and rectangle (182) can be either the ending or

starting part of the multilevel arm. As it can be seen from the drawing, gap (181) features a similar winding shape as the two coupled arms.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5

Drawing 5 in Figure 3 shows one particular embodiment of the multilevel structure and the two arms of different length, a longer arm (111) and a shorter arm (112), that follow a winding parallel path spaced by a gap (122) with a substantially similar shape as each of said arms (111,112). The multilevel structure is based on design from Drawing 16 in Figure 7 and it includes 15 conducting rectangles: a first rectangle (131) being orthogonally connected at one end to a second rectangle (132), said second rectangle being orthogonally connected at a second tip to a first tip of a third rectangle (133), said third rectangle being orthogonally connected at a second tip to a first tip of a fourth rectangle (134), said fourth rectangle being orthogonally connected at a second tip to a first tip of a fifth rectangle (135), said fifth rectangle, parallel to the third rectangle (133), being orthogonally connected at a second tip to a first tip of a sixth rectangle (136), said sixth rectangle being orthogonally connected at a second tip to a first tip of a seventh rectangle (137), said seventh rectangle being orthogonally connected at a second tip to a first tip of a eighth rectangle (138), said eighth rectangle being orthogonally connected at a second tip to a first tip of a ninth rectangle (139), said ninth rectangle, parallel to the seventh rectangle (137), being orthogonally connected at a second tip to a first tip of a tenth rectangle (140), said tenth rectangle, parallel to the sixth rectangle (136), being orthogonally connected at a second tip to a first tip of a eleventh rectangle (141), said eleventh rectangle, parallel to the ninth rectangle (139), being orthogonally connected at a second tip to a first tip of a twelfth rectangle (142), said twelfth rectangle, parallel to the fourth rectangle (134), being orthogonally connected at a second tip to a first tip of a thirteenth rectangle (143), said thirteenth rectangle, parallel to the third rectangle (133), being orthogonally connected at a second tip to a first tip of a fourteenth

rectangle (144), said fourteenth rectangle, parallel to the second rectangle (132), being orthogonally connected at a second tip to a first tip of a fifteenth rectangle (145), being this last rectangle (145) parallel to the first rectangle (131). Rectangles (145, 144, 143, and 142) define the shorter arm (112) of the 5 multilevel structure according to the present invention, while the other eleven rectangles define the longer arm (111). Similar shapes within the scope of this invention could have been used for this purpose, such as the one shown in Figure 11, Drawing 20. In this Drawing 20, the structure is being composed by 10 17 rectangles. Two posting elements (120, 121) are connected, one acting as a short-circuit (120) between the antenna element, and the other one (121) acting as the feeding point for the structure. Within the scope of the present invention, and depending on its application, several frequency responses can be achieved by removing the short-circuit posting (120), and having only the feeding point (121). It is clear the that shape of the gap (122) and the two arms 15 (111, 112) can be changed, as well as the position for the two posting elements (120, 121). This would allow a fine tuning of the antenna to the desired frequency bands in case the desired application would request it. Also, it is shown in this particular embodiment that one edge on the perimeter of first 20 layer (109) is substantially aligned with one of the shorter edges of second layer (110), said second layer featuring a substantially elongated rectangular shape, such that the first layer (109) is covering a portion of the tip region of said second conducting layer or ground-plane (110). In some embodiments, such edge is the preferred one to include the feeding element (121) according 25 to the present invention.

25

Another preferred embodiment is shown in Figure 3, Drawing 6. It shows the same antenna pattern and groundplane configuration than the one described in Drawing 5, but with the addition of an orthogonally connected piece acting as a loading capacitor (123) to the sixth rectangle. This would allow a fine 30 tuning of the antenna to the desired frequency bands by means of the capacitive effect of said extra piece, which is acting as a loading

capacitor(123), with the rest of the structure. Needless to say that the shape of the loading capacitor (123) can be changed, as well as the length, width, and height. Also, depending on the application and the needed frequency response, it can be placed along another rectangle of the structure.

5 Additionally, more than one loading capacitor (123) can be placed on the structure, depending on the application and the required frequency response.

It will be clear to those skilled in the art that the present invention can be combined in a novel way to other configurations, such as the one shown in

10 Drawing 7, Figure 3. In that antenna pattern, the gap that was between the rectangles (139), (140), (141) has been filled out forming an area (125), as well as the gap between rectangles (133), (134), (135), which has been filled out forming an area (126). It is clear that, within the scope of the present invention, several other parts for the winding gap can be filled out as well, depending on  
15 the application and the required frequency bands.

Three other embodiments for the invention are shown in Figure 4. No matter what the final configuration is for the antenna element, the ground-plane can be changed so as to increase the performance of the structure in terms of

20 bandwidth and efficiency. Drawings 8, 9, and 10 show a groundplane (110) characterized in that the portion that is underneath the antenna element or first layer (109) is shaped either as a multilevel structure, a space-filling structure, or a combination of both. According to the present invention, it is preferred that such a portion of ground-plane (110) which includes the gaps defined by the  
25 polygons of said multilevel structure does not extend beyond the area underneath the first layer (109) further than a distance equal to twice the maximum distance between said first and second layers (109) and (110) respectively. On the other hand, drawing 8 is characterized in that besides shorting post (172) between (109) and (110), there is also another  
30 interconnection between said first layer (109) and second layer (110) through a conducting wire or strip (173) connected at the feeding point (171) at one tip,

located at (109), and at the input port (170) at the other tip, located on (110). In other words, conducting wire (173) includes two ends, (170), located on second layer (110), and (171), located on first layer (109).

- 5 In these particular embodiments, shape 113 in ground-plane 110 shows a multilevel structure, being composed by two rectangular slots. It is clear that, within the scope of the present invention, several other multilevel and/or space-filling slot shapes could have been placed, depending on the application and the desired frequency band. Just as an example, but without limiting the
- 10 present invention, Drawings 9 and 10 show two particular configurations for the groundplane shape (113, 114). Both (113) and (114) are portions that are underneath the antenna and are shaped as a multilevel structures. (113) is being formed by two symmetrical slots cut-out onto the ground-plane, and each slot being composed by three rectangles orthogonally connected at their ends. (114) is being formed by two symmetrical slots cut-out onto the ground-plane, and each slot being composed by five rectangles orthogonally connected at their ends.
- 15

Drawing 11 from Figure 5 shows a groundplane (110) shape underneath the antenna being formed by two symmetrical slots (115) and (115') cut-out onto the ground-plane, and each slot (115) and (115') being composed by seven rectangles, that is, composed by a multilevel shape, orthogonally connected at their ends. The two multilevel symmetrical slots (115) and (115') enhance the antenna device in terms of size, VSWR, bandwidth, and/or efficiency.

25

It is clear to those skilled in the art that the present invention covers a whole new set of multilevel and/or space-filling structures for the ground-plane underneath the antenna. For instance, in the embodiment shown in Drawing 12 from Figure 5, the shape (116) for the ground-plane (110) underneath the antenna is being composed by six rectangles, three at each side symmetrically located.

It will be clear to those skilled in the art that the present invention can be combined in a novel way to other prior-art antenna configurations. For instance, the new generation of ground-plane shapes underneath the antenna can be 5 used in combination with prior-art antennas to further enhance the antenna device in terms of size, VSWR, bandwidth, and/or efficiency.

Other preferred embodiments are shown in Drawings 14 and 15 in Figure 6. In those, it is shown that the shape of the antenna elements or first layer (109) can 10 be matched to fit inside the external cover for a particular wireless application. First layer (109) in both Drawings 14 and 15 has a size of 38 x 16.5 x 5.5 mm, and the antenna structure is substantially matched at the frequency bands 824 MHz – 960 MHz and 1710 MHz – 2170 MHz. For both drawings, the shape (117) for the ground-plane (110) underneath the antenna element or first layer (109) 15 has been matched to fit some external components included on the wireless terminals, such as screws, bases, or plastic pieces. Also, some edges of the rectangles composing multilevel structures that is first and second layers (109) and (110) have been replaced by curved segments to ease the mechanical integration of the invention in a typical handheld device. Also, some small holes 20 are placed on (110) to allow screws and other mechanical fixtures to be included in the integration process. It will be clear to those skilled in the art, that those are minor changes on the mechanical configuration that do not play a substantial effect on the essential electromagnetic behavior of the invention, and therefore 25 are included within the scope and spirit of the present invention. Other examples of variations that are included within the scope and spirit of the present invention are shown, without any limiting purpose in Fig. 8, Fig. 9 and Fig.10. In particular, Fig. 10 shows an embodiment 19 wherein the multilevel structure in (110) defines a single slot on the ground-plane (110), while in Fig. 9 said multilevel structure defines at least two slots (as in the case in the embodiment of drawing 30 8). Although not necessary, it is preferred that at least one of the slots defined by

said multilevel structure on second layer (110) is substantially aligned with one of the edges of the outer perimeter enclosing first layer (109).

It is important to stress that the key aspect of the invention is the geometry 5 disclosed in the present invention. The manufacturing process or material for the antenna device is not a relevant part of the invention and any process or material described in the prior-art can be used within the scope and spirit of the present invention. To name some possible examples, but not limited to them, the antenna could be stamped in a metal foil or laminate; even the whole antenna 10 structure including the multilevel structure, loading elements and ground-plane could be stamped, etched or laser cut in a single metallic surface and folded over the short-circuits to obtain, for instance, the configurations in Figures 3, 4, 5, and 6. Also, for instance, the multilevel and/or space-filling structure on the ground-plane might be printed over a dielectric material (for instance FR4, Rogers<sup>®</sup>, 15 Arlon<sup>®</sup> or Cuclad<sup>®</sup>) using conventional printing circuit techniques, or could even be deposited over a dielectric support using a two-shot injecting process to shape both the dielectric support and the conducting multilevel and/or space-filling structure.

**CLAIMS**

1.- A multiband antenna comprising a first conducting layer and a second conducting layer, said first conducting layer acting as a radiating element being placed over said second layer, said second layer acting as a ground plane or ground counterpoise, characterized in that said first layer has a feeding point, wherein said feeding point is the starting point for a first shorter and a second longer arms, said arms forming a multilevel structure for said multiband antenna, wherein both arms define a winding path over second layer, wherein said second longer arm is folded upon itself to run in parallel with the winding path of said first arm, such that a gap between both arms is formed, said gap following substantially the same winding path as said first and second arms on said multilevel structure.

15 2.- A multiband antenna comprising a first conducting layer and a second conducting layer, said first conducting layer acting as a radiating element being placed over said second layer, said second layer acting as a ground counterpoise, characterized in that at least a portion of the area on the second layer which is underneath said first layer is shaped either as a multilevel structure, a space-filling structure or a combination of both.

25 3.- A multiband antenna according to claim 1 or 2, said antenna, characterized in that said first layer acting as a radiating element has a feeding point, wherein said feeding point is the starting point for a first shorter and a second longer arms, said arms forming a multilevel structure for said multiband antenna device, wherein both arms define a winding path over second layer, wherein said second longer arm is folded upon itself to run in parallel with the winding path of said first arm such that a gap between both arms is formed, said gap following substantially the same winding path as said first and second arms, and wherein 30 at least a portion of the area on the second layer which is underneath said first

layer is shaped as a multilevel structure or a space-filling structure or a combination of both.

- 4.- A multiband antenna, according to claim 1, 2 or 3, characterized in that the  
5 only interconnection between said first layer one and said second layer two is through a conducting wire or strip connected at the feeding point at one tip, located on said first layer, and at the input port at the other tip, located on said second layer.
- 10 5.- A multiband antenna, according to claim 1, 2, 3 or 4 characterized in that said second layer or ground counterpoise has a substantially rectangular or elongated shape, wherein said first conducting layer has one of its edges substantially aligned together with one of the shorter edges of said second conducting layer, such that said first layer is covering a portion of the tip region over said second  
15 conducting layer or ground counterpoise.
- 20 6.- A multiband antenna according to claim 2, 3 or 5 wherein the portion of said second layer which is shaped either as a multilevel structure, a space-filling structure or a combination of both is extended beyond the area underneath said first layer up to at most a distance equal twice the maximum distance between  
25 said first and second conducting layers.
- 25 7.- A multiband antenna, according to claim 5 or 6 wherein said first layer includes a feeding point, said feeding point being connected to the input port, located on said second layer, by means of a conducting wire or strip, said feeding point being placed at the edge of the first layer which is substantially aligned with the shorter edge of said second layer.
- 30 8.- A multiband antenna according to claim 1, 3, 4, 5, 6 or 7, characterized in that said first layer has a feeding point, wherein said feeding point is the starting point for a first shorter and a second longer arms in a multilevel structure, wherein said

first shorter arm is composed by at least four rectangles, said four rectangles being sequentially interconnected through their shorter edges, wherein said second longer arm is composed at least by eleven rectangles, said eleven rectangles being sequentially interconnected through their shorter edges,  
5 wherein both multilevel arms define a winding path over second layer, wherein said second longer multilevel arm is folded upon itself to run in parallel with the winding path of said first multilevel arm such that a gap between both arms is formed, said gap following a substantially winding path similar to those of said first and second multilevel arms.

10

9.- A multiband antenna, according to claim 1, 3, 4, 5, 6, 7 or 8 wherein at least one of the edges of the polygons composing the multilevel structure in layer one is replaced by at least a curve.

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10.- A multiband antenna, according to claim 1, 2, 3, 4, 5, 6, 7, 8 or 9 wherein said multilevel structure in second layer is composed by at least three rectangles, a first rectangle being substantially aligned along a central axis upon second conducting layer or ground-plane, said first rectangle being connected through one of its shorter edges to said ground-plane, a second of said rectangles being  
20 connected to a first longer edges of said first rectangle, a third of said rectangles being connected to the second longer edge of said first rectangle.

25

11.- A multiband antenna according to claim 10 wherein said multilevel structure in second layer is composed by seven rectangles, the first of said seven rectangles interconnecting by means of its two shorter edges two disjointed solid conducting areas of second conducting layer or ground-plane, wherein the second, third and fourth of said seven rectangles are substantially parallel to each other and are connected by one of their tips to the first longer edge of said first rectangle, wherein the fifth, sixth and seventh of said seven rectangles are  
30 connected by one of their tips to the second longer edge of said first rectangle, such that the spacing between said rectangles and between said rectangles and

the two disjointed solid conducting areas on layer two define eight parallel air or dielectric gaps.

12.- A multiband antenna, according to claim 2, 3, 4, 5, 6, 7, 8, or 9 wherein said 5 multilevel or space-filling structure on second conducting layer defines a single slot on said ground-plane.

13.- A multiband antenna, according to claim 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11 10 wherein said multilevel or space-filling structure on second conducting layer defines at least two slots on said ground-plane.

14.- A multiband antenna, according to claim 2, 3, 4, 5, 6, 7, 8, 9, 12, or 13 15 wherein said multilevel or space-filling structure on second conducting layer defines at least a slot on said ground-plane, said slot being substantially aligned underneath one edge of first conducting layer.

15.- A multiband antenna, according to any of the preceding claims, wherein said 20 first layer and second layer are interconnected by at least a wire or conducting strip, said wire or strip substantially acting as a short-circuit or low impedance current path between said first and second conducting layers.

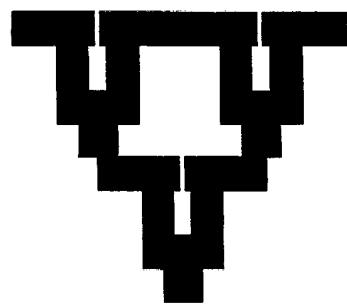
16.- A multiband antenna according to any of the preceding claims, wherein the 25 volume between said first conducting layer and said second conducting layer is smaller than  $38 \times 16.5 \times 7.5 \text{ mm}^3$  and the antenna is substantially matched at the frequency bands 824 MHz - 960 MHz and 1710 MHz – 2170 MHz.

17.- A multiband antenna, according to any of the preceding claims, wherein said 30 second layer is one of the layers of the printed circuit board in a handheld wireless terminal such as a cellular phone, a wireless phone, a personal digital agenda (PDA), or a palmtop computer.

1 (Prior Art)



2 (Prior Art)



3 (Prior Art)



4 (Prior Art)

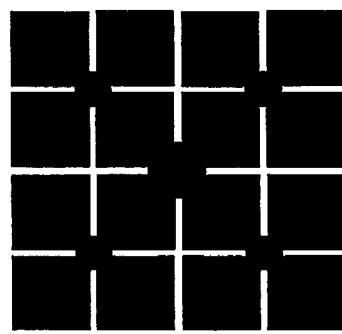


FIG.1

3 (Prior Art)



3 (Prior Art)

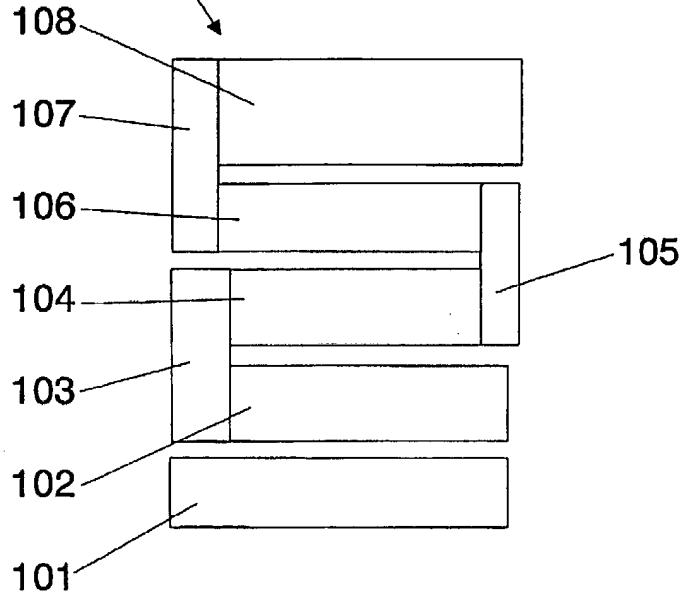


FIG.2

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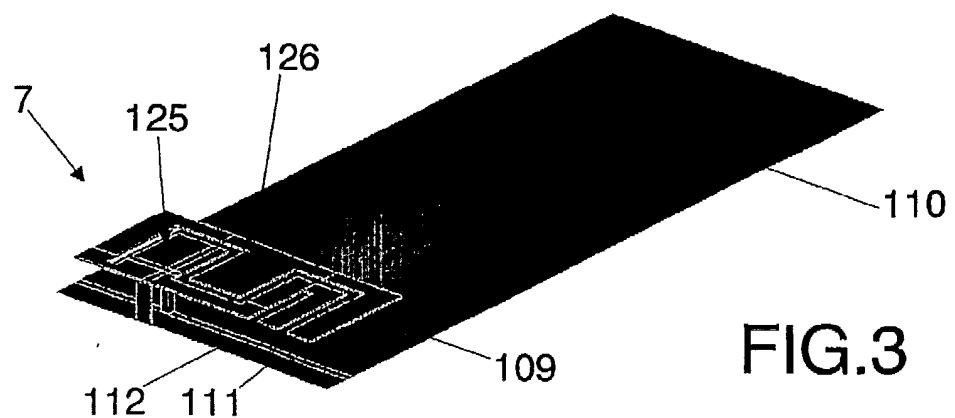
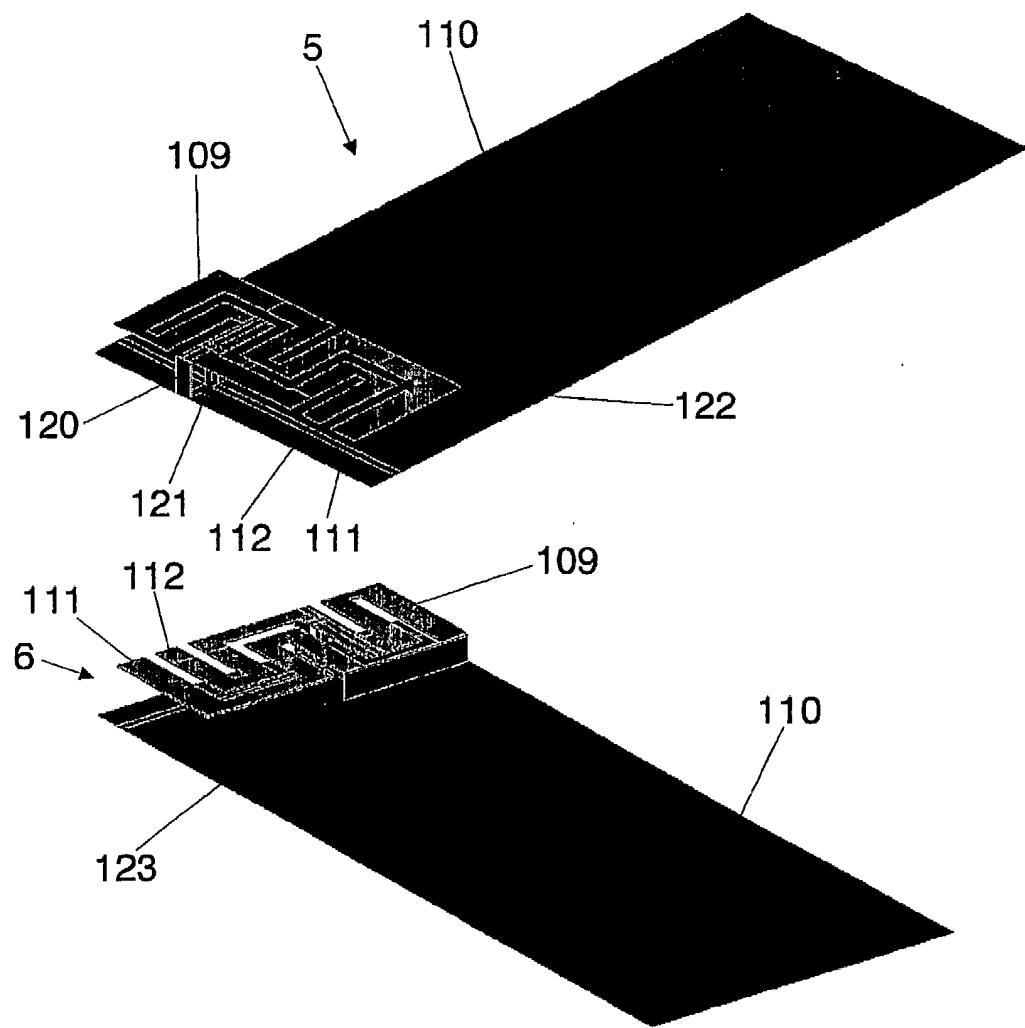


FIG.3

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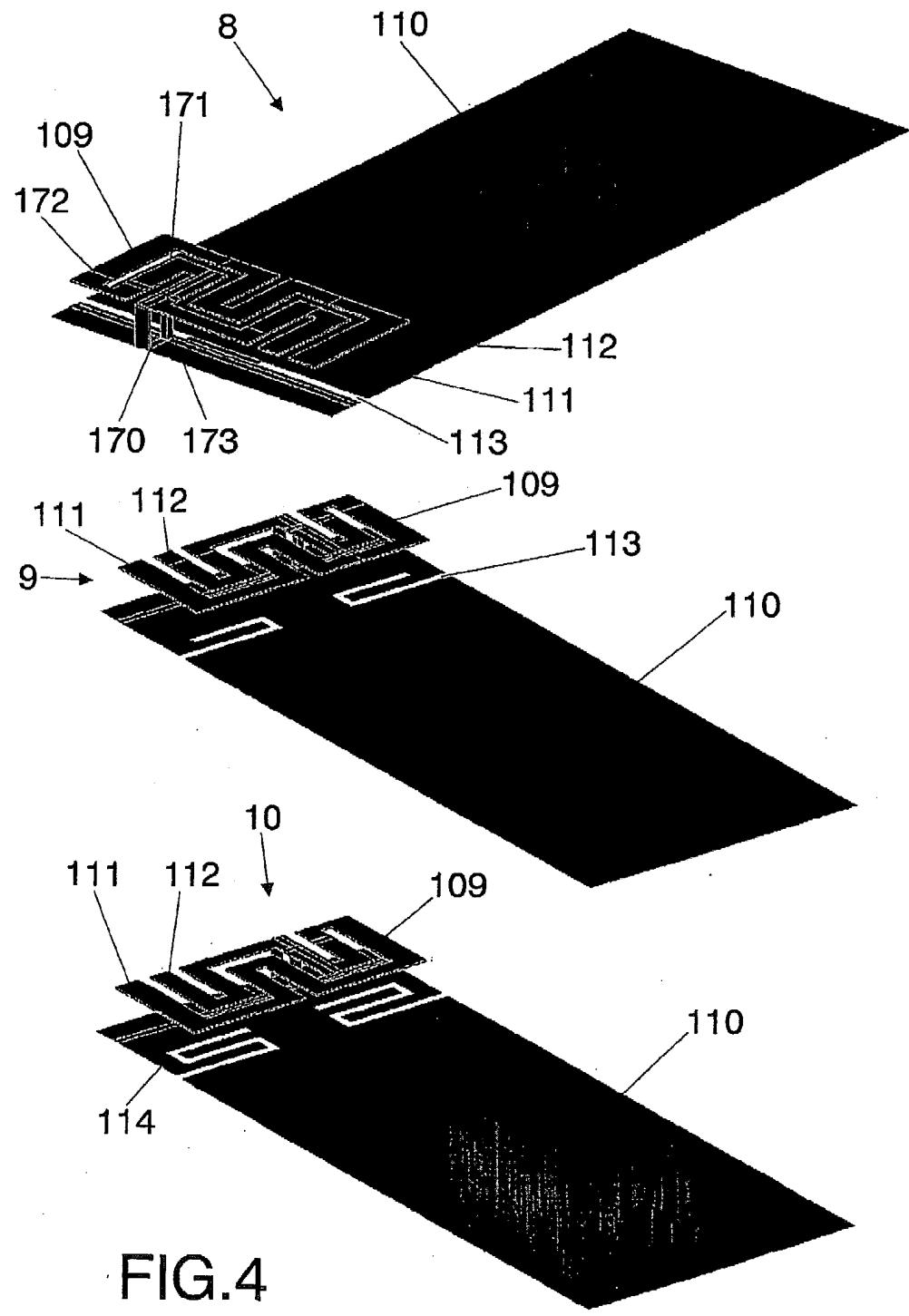


FIG. 4

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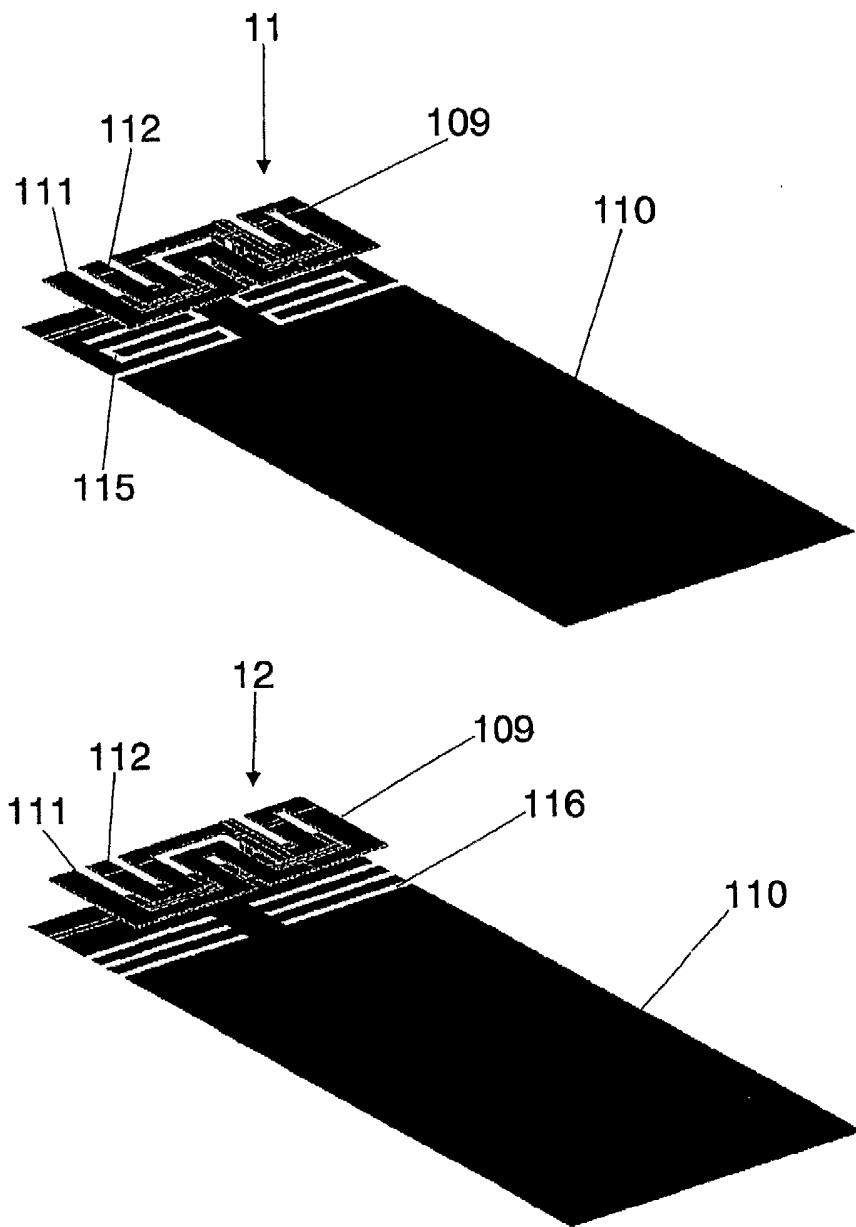


FIG.5

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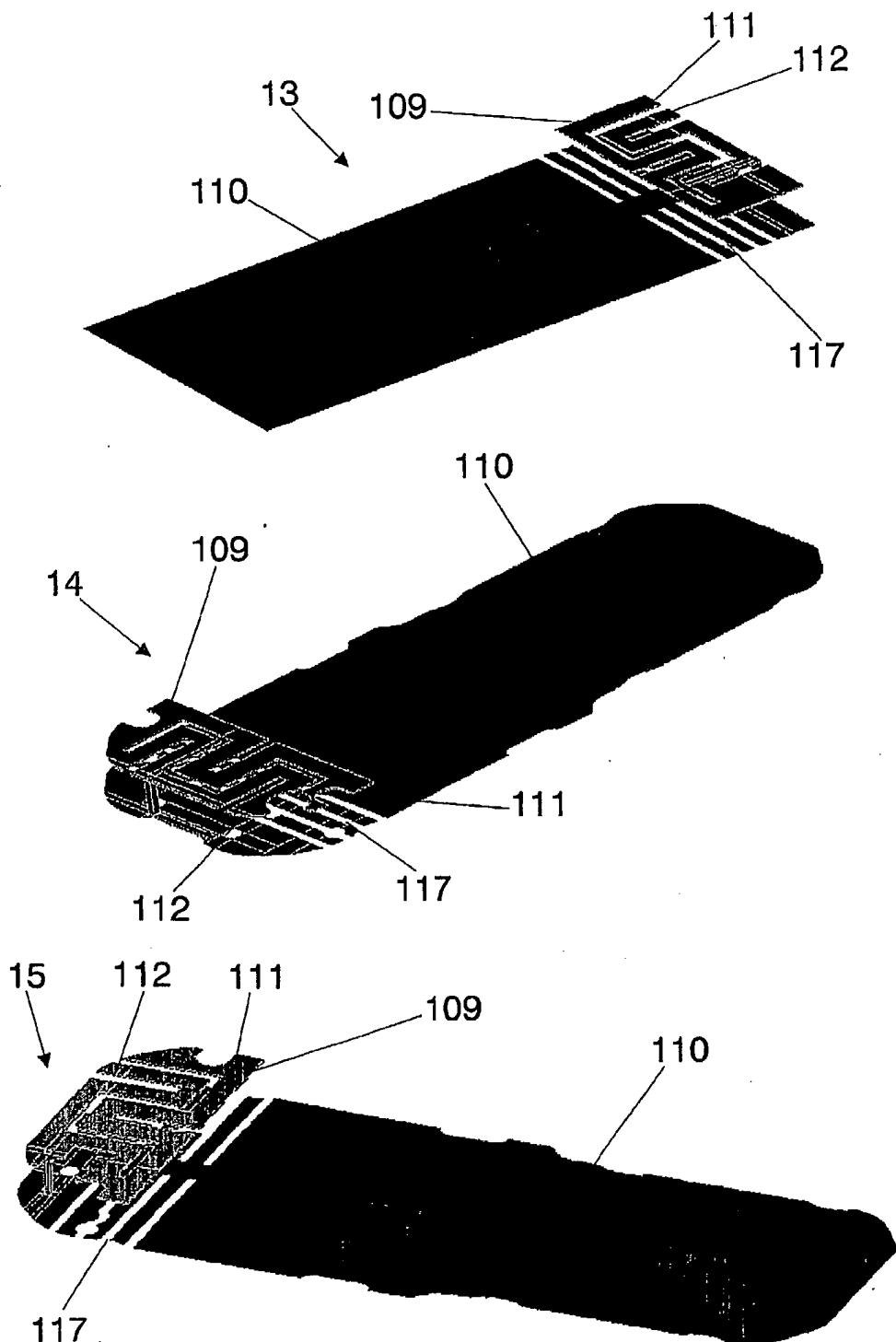


FIG.6

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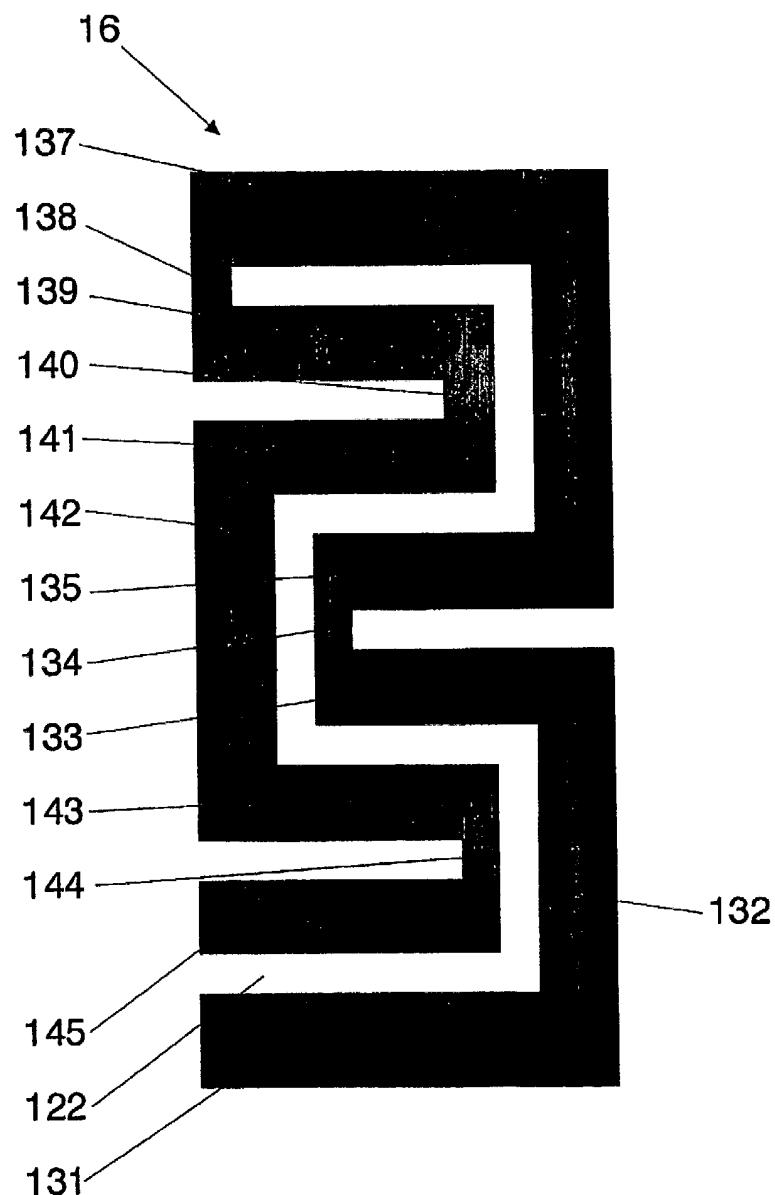


FIG.7

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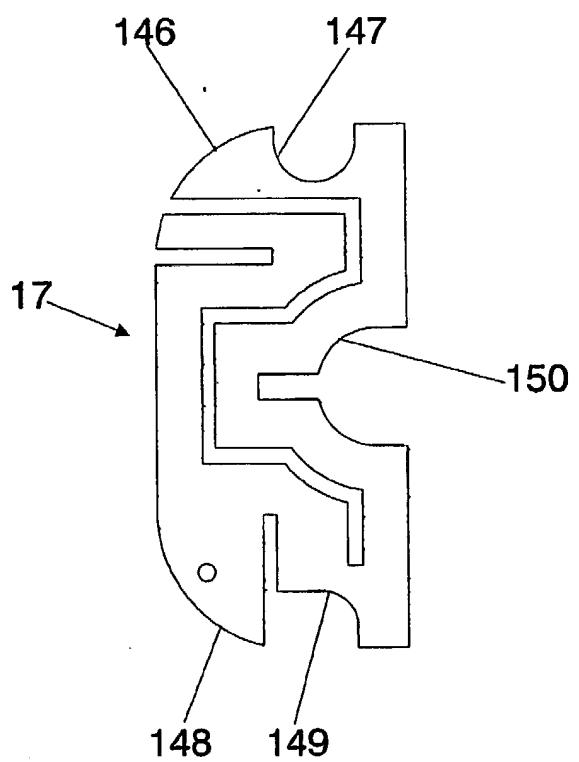


FIG.8

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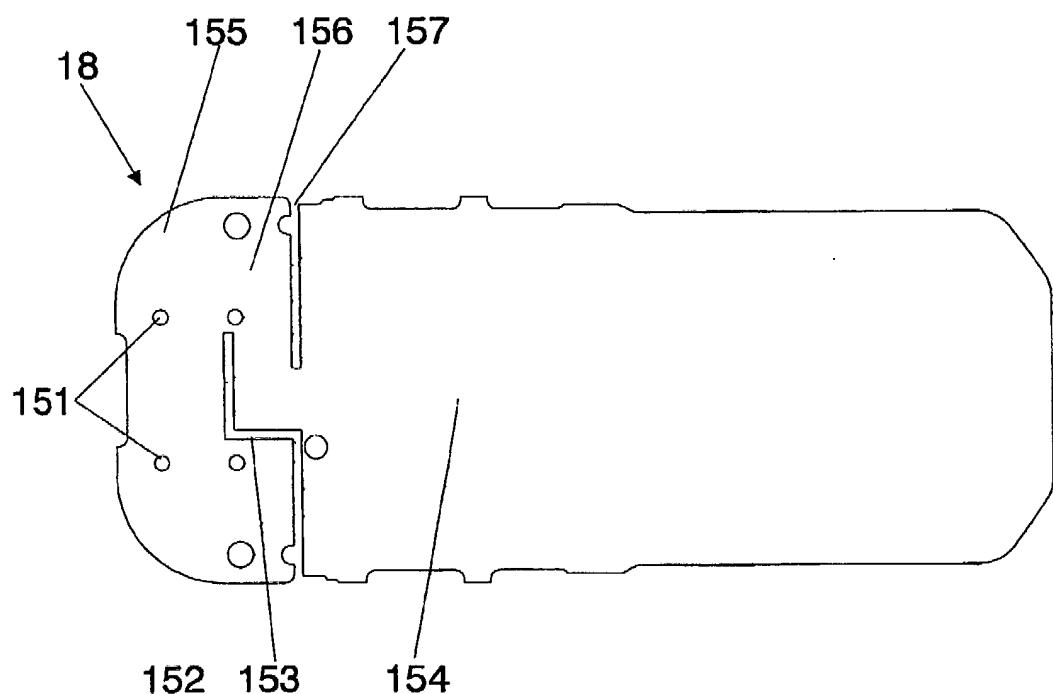
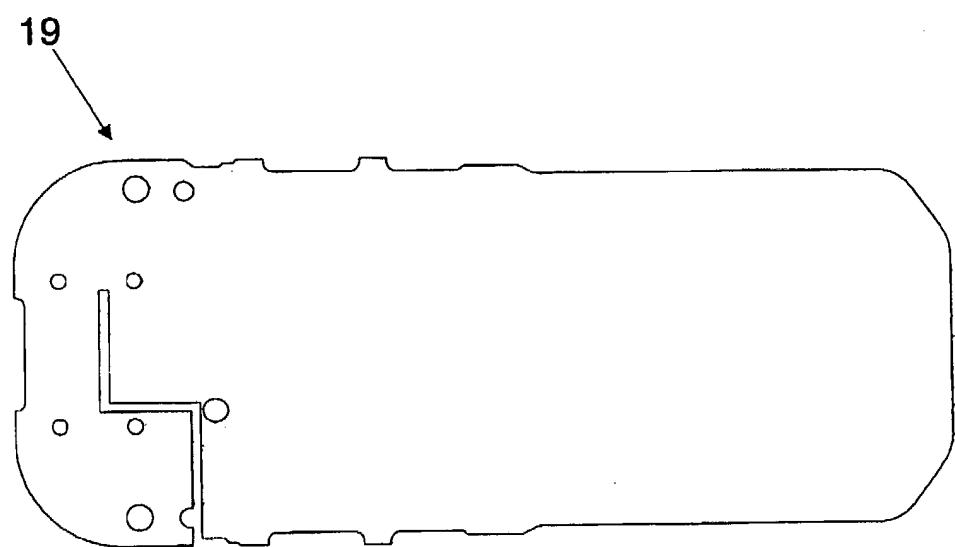


FIG.9

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**FIG.10**

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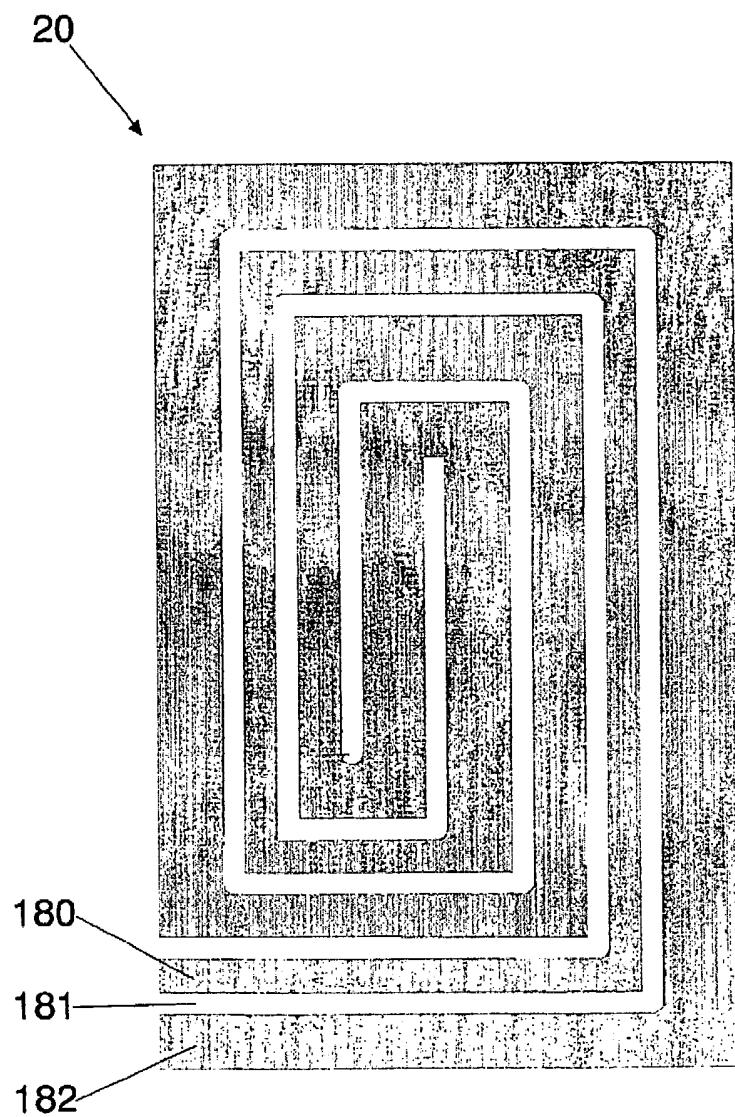


FIG.11

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/EP 02/07002

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 H01Q1/24 H01Q1/38 H01Q5/00 H01Q1/36

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 140 975 A (COHEN NATHAN) 31 October 2000 (2000-10-31)	1-3,5, 8-12,14, 16,17
Y	the whole document ---	4,6,7, 13,15
Y	EP 1 026 774 A (SIEMENS AG) 9 August 2000 (2000-08-09) the whole document ---	4,6,7,15
Y	EP 1 148 581 A (KOSAN INFORMATION & TECHNOLOGI) 24 October 2001 (2001-10-24) the whole document ---	13
X	WO 02 01668 A (PENN STATE RES FOUND) 3 January 2002 (2002-01-03) figure 14 ---	1 -/-

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Patent family members are listed in annex.

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Date of the actual completion of the International search

23 January 2003

Date of mailing of the International search report

05/02/2003

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 6 239 765 B1 (HILL ROBERT ET AL) 29 May 2001 (2001-05-29) figure 9 -----	1

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

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PCT/EP 02/07002

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			JP	2001085929 A		30-03-2001
			WO	0052783 A1		08-09-2000
			US	2002033772 A1		21-03-2002

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